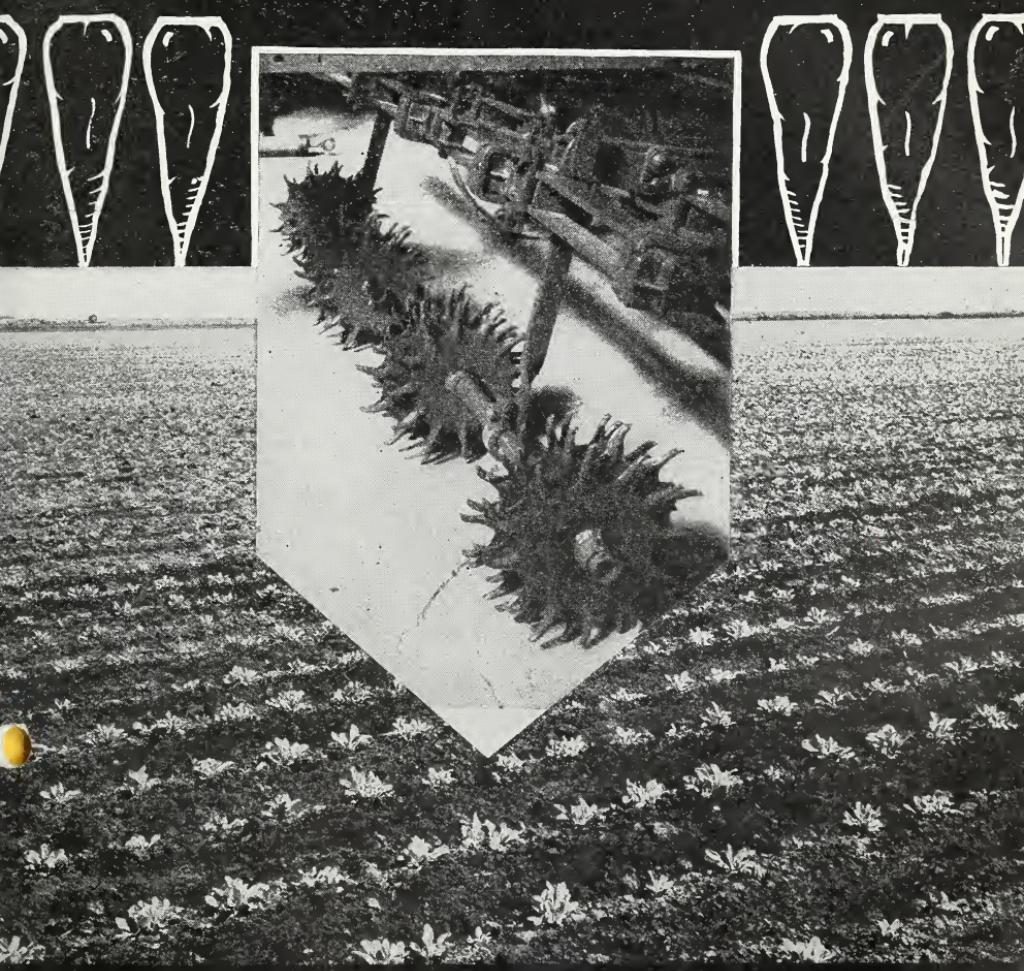


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Developments in Mechanical Equipment and Methods in **SUGAR-BEET PRODUCTION**



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DEVELOPMENTS IN MECHANICAL EQUIPMENT AND METHODS IN SUGAR-BEET PRODUCTION¹

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INTRODUCTION

This circular is intended to describe the most recent developments in sugar-beet-production equipment and to give sugar-beet growers the results of tests of methods and equipment designed to increase yields and reduce costs, and to suggest to manufacturers possible improvements in sugar-beet-production machinery.

Much information on the cost of producing sugar beets has been compiled from surveys made in the United States. The results of these investigations are contained in a number of State and Federal publications (4, 5, 8, 9, 10, 11, 15).²

These bulletins show that man labor is one of the major costs, ranging from 79.5 to 181 man-hours per acre and averaging 123 man-hours. In these cases the low and high labor requirements do not necessarily represent good and poor practice, but rather a variation in field conditions together with differences between large-scale tractor operations where plows of 4 or 5 or more bottoms are used and where 12 or 16 rows are planted or cultivated at one time and smaller-scale production where horses are largely used and 2 or 4 rows are planted or cultivated at once.

Man labor required for sugar-beet production is divided into two general classifications: Farmer labor and contract labor. Farmer labor, often referred to as machine labor to distinguish it from that done by hand, consists in plowing and other seedbed preparation,

¹ These studies were carried on in cooperation with the Colorado and California Agricultural Experiment Stations.

² Italic numbers in parentheses refer to Literature Cited, p. 37.

cultivation, irrigation, lifting beets, and other similar work usually done by the regular farm help. Contract or hand labor includes blocking, thinning, hoeing, pulling, topping, and sometimes loading. Much of this hand work is done on contract at a specified rate per acre or per ton.

From two of the bulletins mentioned (4, 8) the division of man labor is found to be—

Farmer labor	man-hours per acre	50.75, or 43.2 percent
Contract labor	do	66.66, or 56.8 percent
Total	do	117.41

The division varies because fewer farmer hours are frequently the result of more contract hours.

Peck (11) says: "Professional beet workers (contract workers) are able to perform the hand labor for an acre of beets in 20 percent less time than is needed by the average grower." This writer reported 102.97 man-hours were required for the contract work when done by the grower as compared with 83.42 man-hours when performed by the professional contract worker.

Detailed studies by the Bureau of Agricultural Engineering on a 10-acre field on a farm at Fort Collins, Colo., in 1933 showed requirements per acre of:

	Man-hours
Farm labor	54.82
Contract labor	82.6

Since the "contract" work on this farm was performed by the grower himself, it might be reasonable to discount the contract labor-hour requirements by 20 percent as reported above, thus showing labor requirements per acre to be:

	Man-hours
Farm labor	54.82
Contract labor	66.08
Total	120.90

showing a close correlation with previous findings.

The results of a detailed study of labor requirements on this farm are given here:

Man-hours required per acre for raising sugar beets on the agricultural engineering farm, Fort Collins, Colo.

Operation:	Man-hours
Manuring	7.7
Plowing	3.5
Harrowing	3.47
Planting	1.5
Crust breaking	2.0
Cross blocking	1.05
Cultivating	4.35
Thinning	32.3
Hoeing	9.6
Irrigating	12.3
Pulling weeds	4.8
Lifting beets	4.45
Topping	35.9
Hauling	14.5
Total	137.42

Not only is the cost of labor a large item (in the case just cited 79 percent of the total operating cost) but, because of peak demands for labor for thinning and hoeing and harvest, it is difficult to obtain sufficient help when needed.

Figure 1 shows the hours of both farmer and contract labor required each month to grow an acre of sugar beets in Colorado. For most of the other beet-growing districts the seasonal peaks are similar though the dates may vary somewhat.

In California, however, where sugar-beet harvest begins in July and continues on into December, the fall or harvest labor peak is less sharp than in districts where the beets are harvested in September, October, and November, and is less than the spring labor peak.

Figure 2 shows the 1931 to 1934 average seasonal demand for labor expressed in men required per thousand acres of sugar beets in the Sacramento Valley, Calif. The lines showing the contract-labor peak are based on data obtained from the labor office of the Spreckels Sugar Co., and the constant or machine-labor demands are estimates of that office.

Because of the increasing difficulty of meeting the peak labor requirements, and because any reduction of these peaks makes for a more stable condition of labor, and since hand labor makes up the major part of the peaks, the obvious place to make labor reductions is in thinning, hoeing, harvesting, and hauling.

Substantial progress has been made in the sugar-beet harvester, the eventual adoption of which should do much in reducing the peak labor load at the end of the season. Considerable progress has been made in lowering the spring peak load by the general adoption of mechanical blocking. Improved planters may make some sort of mechanical thinning practical which would tend to equalize the labor load throughout the season and do much toward lowering the cost of raising beets. A general improvement in sugar-beet tools has gone far to improve the quality of work which is reflected in lowered costs of production and better beets.

CHARACTERISTICS OF SUGAR-BEET SEED

The characteristics of sugar-beet seed were studied especially in the Bureau of Agricultural Engineering laboratory at Davis, Calif. Motor-driven planters made it possible to determine the effect on accuracy of planting of such factors as seed density, volume of seed above the planter plates, and speed of plates.

Sugar-beet seeds, so-called, are seed balls made up of a rough, hard, corky or woody covering enclosing from one to five or more true seeds. The seed balls will stand considerable abuse without

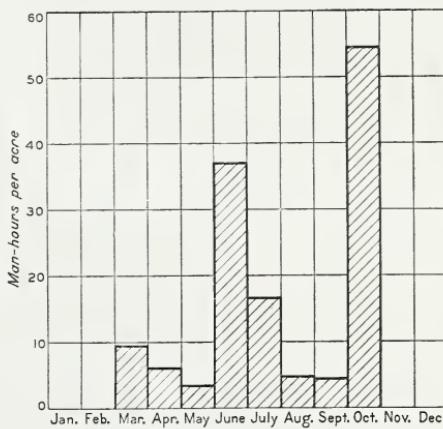


FIGURE 1.—Seasonal distribution of man-labor required for sugar-beet growing on the agricultural engineering farm near Fort Collins, Colo.

damage to the enclosed germs. Balls which produce several seedlings, especially when dropped two or three at a time, cause one of the difficulties in developing improved equipment. Also, it is difficult to devise methods for materially reducing the time required for thinning the stand to single beets properly spaced in the row.

Germination tests have been made under favorable conditions, both in the Bureau laboratory and in the field, using a seed of high viability. In the laboratory where conditions for germination were ideal, the average number of sprouts per seed ball was approximately two with the better seed. Similar tests with the larger sizes of screened seed averaged slightly more than two and one-quarter

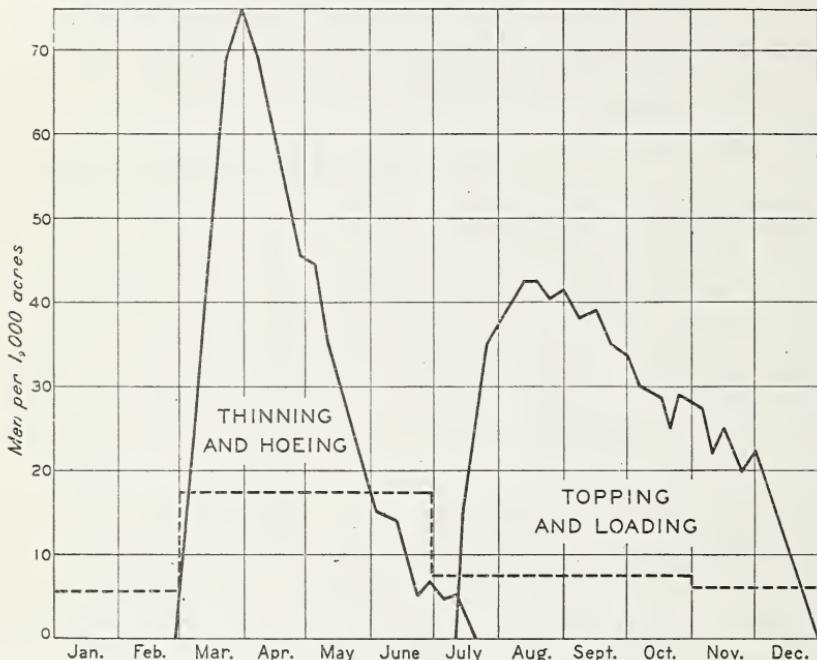


FIGURE 2.—Seasonal distribution of man-labor required for sugar-beet growing in the Sacramento Valley, Calif.

sprouts per ball. In field tests the larger sizes of seed averaged about two sprouts per germinating seed ball, while unscreened seed averaged one and three-quarter sprouts and the smaller sizes of screened seed averaged one and one-quarter sprouts per germinating ball. With an average of only one and one-half or, at the most two sprouts per germinating seed ball, there is a possibility of obtaining enough single seedlings to produce a stand that can be thinned more rapidly, provided the seeds are more uniformly distributed in planting.

Experimental trials by Bureau engineers have proved the mechanical feasibility of planting individual seed balls at regular intervals in the row. This should make mechanical thinning practical.

Sugar-beet seed balls normally range from eight sixty-fourths to twenty sixty-fourths of an inch in diameter. A No. 11 or 12 round-hole screen (having holes eleven or twelve sixty-fourths of an inch

in diameter) will separate average sugar-beet seed into two approximately equal parts by weight.

The density of the seed varies with the size and the amount of corky edges worn off the balls in threshing or subsequent handling. It usually varies from 18 to 20 pounds per bushel test weight (1, 2), 19 being a fair average.

The seed-ball count of unscreened seed is quite variable, usually ranging from 15,000 to 28,000 per pound, a fair average being between 20,000 and 22,000. Domestic seed is somewhat smaller than European seed. Average seed planted at the common rate of 20 pounds per acre will provide approximately 15 to 18 balls per foot of row.

Decorticated seed is produced by machining off the outer and softer portions of the ball. Such seed has been used experimentally as it is heavier and smoother and flows more easily through the planter.

Until the last few years most of the sugar-beet seed has been imported from Europe. The recent development in this country of disease-resistant strains of beets, particularly strains resistant to curly top, and the resulting rapid development of a supply of seed from them, has resulted in much of our sugar-beet seed being home grown, the amount increasing each year. Sugar companies have imported the foreign seed and supplied it to their contracted growers during the past few years. They are now contracting also with producers for the disease-resistant domestic seed, and it is available particularly for late planting where curly top might be serious.

PLANTING EQUIPMENT

INITIAL STANDS

Initial stands, though affected by seeding rate, seed viability, moisture and weather conditions, insect damage, and other factors, measure the effectiveness of a planter or drill in correctly opening furrows and placing and covering the seed. Stands are described in several ways. The grower speaks of his stand as "good," "fair," or "poor" and often describes one that is satisfactory as a "100 percent" stand. By "100 percent" he means a stand that can be commercially thinned to give the desired number of plants, usually 100 to each 100 feet of row.

These methods are too general for investigational work, and two other methods of expressing stands are used. The one used up until the past few years is that of counting the seedlings in 100 inches of row, taking the average of several such counts to express the initial stand of a field or plot. This method is tedious, particularly if the seedlings are 2 or 3 inches high, and it gives the number of seedlings without respect to their distribution in the row. As the objective is to have single beets more or less uniformly spaced, it is not of particular interest to know whether there is one or several seedlings in a given inch, especially as far as obtaining a desirable thinned stand is concerned. Of course, the more seedlings per inch the more difficult it is to thin the group to a single seedling and the more danger there is of damaging the roots of the plant wanted while removing the undesired ones or of accidentally pulling out all of the seedlings in the group.

Mechanical-blocking studies to determine the correct size of block led the Bureau to devise a system that consists in counting the percentage of inches of row containing seedlings, irrespective of the number of plants in a given inch. This method of counting, now very generally adopted, is less tedious, particularly for the better

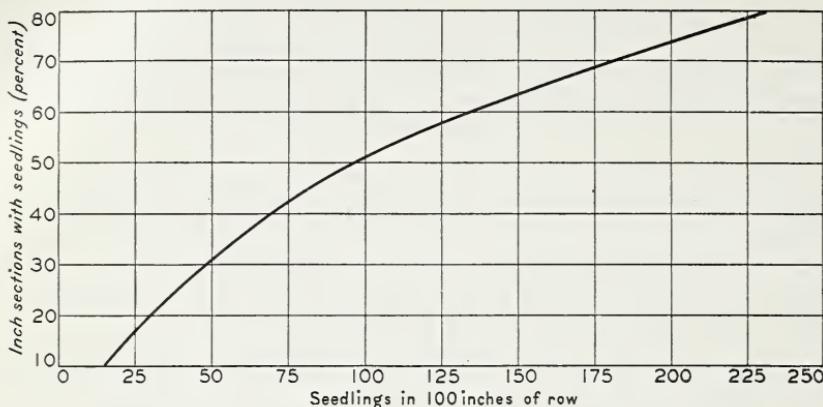


FIGURE 3.—Relationship between sugar-beet initial-stand counts expressed in seedlings per hundred inches of row and in percent of inches of row containing seedlings.

stands, as only the blank inches need be counted and the stand obtained by subtraction from 100. Furthermore, it gives a better indication of the distribution of the seedlings in the row and a count that is much better adapted for use in predetermined thinned stands following mechanical blocking, mechanical thinning, or hand thin-

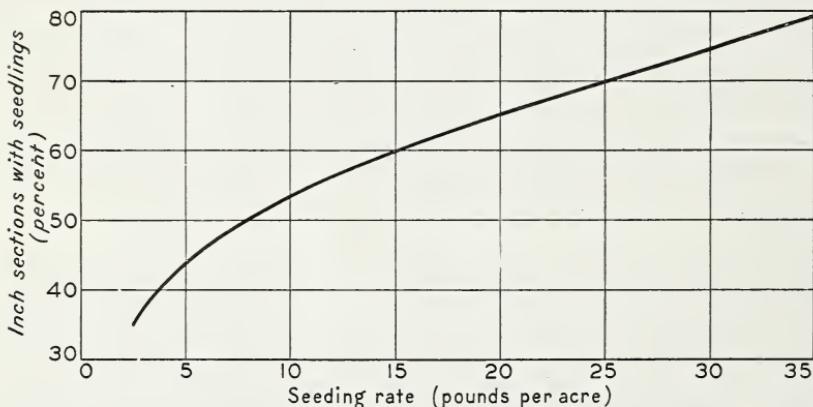


FIGURE 4.—Germination stands corresponding to different seeding rates for a set of favorable germination conditions.

ning. A convenient device for making such counts is a 100-inch stick, hinged in the middle for convenience in carrying, marked with cross lines 1 inch apart. It is laid down along the row, and a count made of the number of inches either with or without beets, depending upon which is the smaller. Several counts are made and the average taken for the field.

Initial-stand counts made in this way rarely are higher than 70 percent, and anything from 60 to 70 percent is an excellent stand. Stands of from 40 to 50 percent are good, while those less than 30 percent are poor. It should be understood that satisfactory after-thinning stands of 100 beets per 100 feet of row can easily be obtained if from 40 to 50 percent, or even less, of the inches of the row contain seedlings. Such a stand might be described by some as "100 percent."

Initial-stand counts have been made by Bureau engineers in a number of fields in California by the two methods to determine the correlation. The curve in figure 3 shows the average correlation. The relationship varies somewhat with the uniformity of planting. With hill planting where several seed balls are dropped together followed by several inches of row without any seed, the correlation curve would be below that shown in figure 3, while very uniform seed distribution would raise the curve above the one shown.

Initial stands vary uniformly through the usual range of seeding rates, other conditions being the same. Curves showing the relation between seeding rate and initial stand are different for different sets of conditions. Figure 4 shows such a curve for a favorable set of conditions.

PLANTERS

The sugar-beet planters or drills in common use are of two types, those with a plate feed and those with a fluted or force feed. The plate-feed planters can be equipped with different plates having specially-shaped seed cells adapted for different kinds of beans and some other crops. Some of the fluted-feed drills have adjustments permitting the planting of other crops than beets.

The plate-feed planter drops the seed in small bunches spaced at intervals depending upon the number of seed cells in the plate and upon the gear and corresponding speed of the plate. Actually the seed in dropping down the tube do not remain bunched but are scattered more or less uniformly in the row unless the planter travels very slowly. The drilling distance, or theoretical spacing between seed groups dropped with the plate planter, becomes larger for the lower seeding rates, thus making for a less uniform seed distribution in the row. Seed from the fluted feed flows in a more nearly steady stream. The more uniform the seed distribution and corresponding initial stand, if not too thick, the more rapidly the plants can be thinned to a satisfactory stand. For this reason the plate planter usually is not so satisfactory as the fluted-feed type for the smaller seeding rates of less than 15 pounds per acre.

FURROW OPENERS

Furrow openers on beet drills are usually either of the runner or the double-disk type, though hoe-type openers are available on some drills. While runner openers, sometimes called shoe openers, cost less, there is, apparently, a larger saving in using disk openers because better initial stands are obtained with them. Repeated experiments in California and Colorado over a period of 5 years show that initial stands with disk openers average approximately 16 percent better than with runner openers.

Results of the experiments with the different furrow openers are given in table 1. The initial stands are expressed as the percent of inches of row containing beet seedlings and are tabulated together with their standard errors. In these experiments the disk and runner openers were mounted on the same drill with pressure arms and springs alike so that seeding rate and germination conditions were the same.

TABLE 1.—*Initial stands of disk- and runner-type beet drill furrow openers*

Year	State	Disk opener		Runner opener	
		Stand	Standard error	Stand	Standard error
1937	Colorado	Percent		Percent	
1936	do	37.9	±1.4	26.38	±1.6
1935	do	58.2	±1.0	56.4	±1.2
1935	do	73.0	±1.3	68.3	±1.2
1935	do	56.0	±3.3	45.37	±3.7
1935	do	50.5	±3.8	43.12	±2.6
1935	do	52.6	±2.5	47.77	±2.5
1935	do	75.75	±2.8	64.37	±3.6
1934	California	63.2	±1.6	52.8	±1.3
1934	Colorado	46.9	±1.5	48.1	±1.3
1933	California	61.8	±2.8	54.2	±1.3
1933	Colorado	69.0	±3.6	49.0	±3.7
Average		58.62	±.81	50.52	±.81

SEEDING RATE AND CALIBRATION

Before planting starts, the seeding rate of the planter should be checked with the seed to be used. A plate planter should be checked to see that the right plates, all of the same number, are in place. On the other type planter, the "flopper" doors above double-run force feeds or adjustable gates under the fluted feeds should all be in the same position.

The planter can be easily calibrated in either of two ways:

First way: In the barnyard or shop, set the tongue to give the machine the angle at which it works in the field, and then jack it up until the drive wheels clear the ground. After arranging containers to catch the seed, turn the drive wheels a predetermined number of revolutions. The seed dropped can be caught in pans placed under the openers or the seed spouts can be removed from the openers and the seed caught in paper bags tied to the spouts. The seed can then be weighed and the seeding rate calculated.

It takes 26,136 feet of beet rows spaced 20 inches apart to equal 1 acre; or it takes 6,534 feet with a four-row drill. A tenth of an acre requires 653.4 feet of forward travel with a four-row drill, and this can be converted to wheel turns by dividing 653.4 by the distance around a wheel measured in feet.

Second way: Most drills can be even more easily calibrated in the field. The flexible seed spouts need only be removed from the openers and paper bags tied over their bottom ends, allowing enough space below the end of the spout for seed accumulation so that it will not back up into the tubes. Then, by setting the furrow openers down in planting position, which throws the planter mechanism into gear, and driving forward 653 feet (with a four-row machine), the seed

for a tenth of an acre can be caught and weighed. If a sufficiently sensitive scale is available, the uniformity of seeding rate to the openers can be checked by weighing the seed caught in each bag. Then the sum of the four multiplied by 10 gives the seeding rate per acre. On some drills the fluted castings which regulate the feed to each opener are clamped to the square feed shaft which turns the castings as well as shifts them for changing the seeding rate. If the feeds to all openers are not uniform, they can be equalized on this type of drill by loosening the clamp bolts and moving these castings slightly on the square shaft.

Seeding rates vary for different districts and different seasons of the year, usually ranging from 18 to 20 pounds per acre. However, the sugar companies maintain fieldmen in their respective districts whose business it is to be informed on such matters.

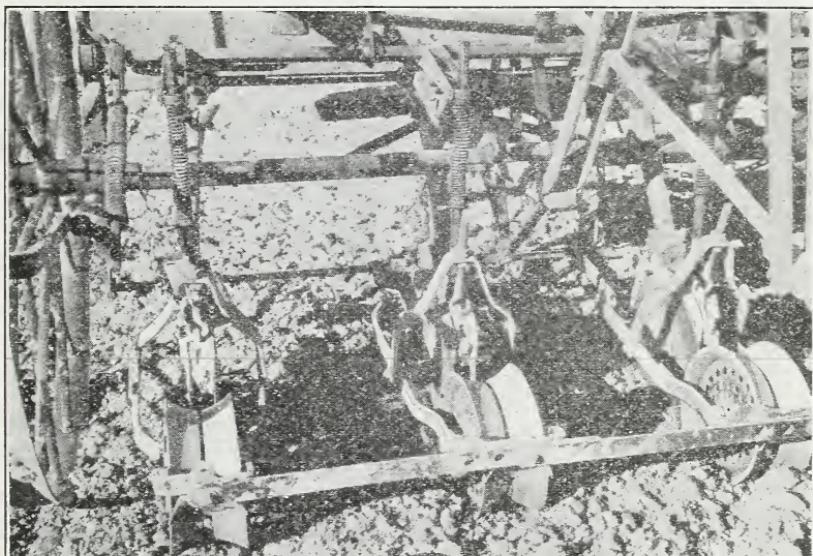


FIGURE 5.—A fluted-feed, disk-opener drill with depth bands removed and openers carried by the press wheels which control the planting depth.

REGULATING PLANTING DEPTH

The depth of planting with runner openers is regulated by setting the press wheels up or down in the opener casting. They can all be set alike and at the desired depth by fixing the tongue at working height, blocking the planter wheels up an amount equal to the depth of planting, lowering the runner openers to the ground or floor with the depth-control lever, and adjusting the press wheels to clear the ground or floor by the desired depth. A board having a thickness equal to the planting depth can be placed under all four sets of press wheels, and they can be set down to it. On some runner-opener planters the runners are adjustable up and down in the frames or drawbars that carry the press wheels. On these the press wheels can be lowered with the depth-control lever to rest on the board and the runners set down to the ground. As runners become

worn and dull, they require more pressure to make them penetrate to the desired depth.

The depth of planting on disk-opener drills is usually regulated by adjustable depth bands fastened to the disk blades. The size of

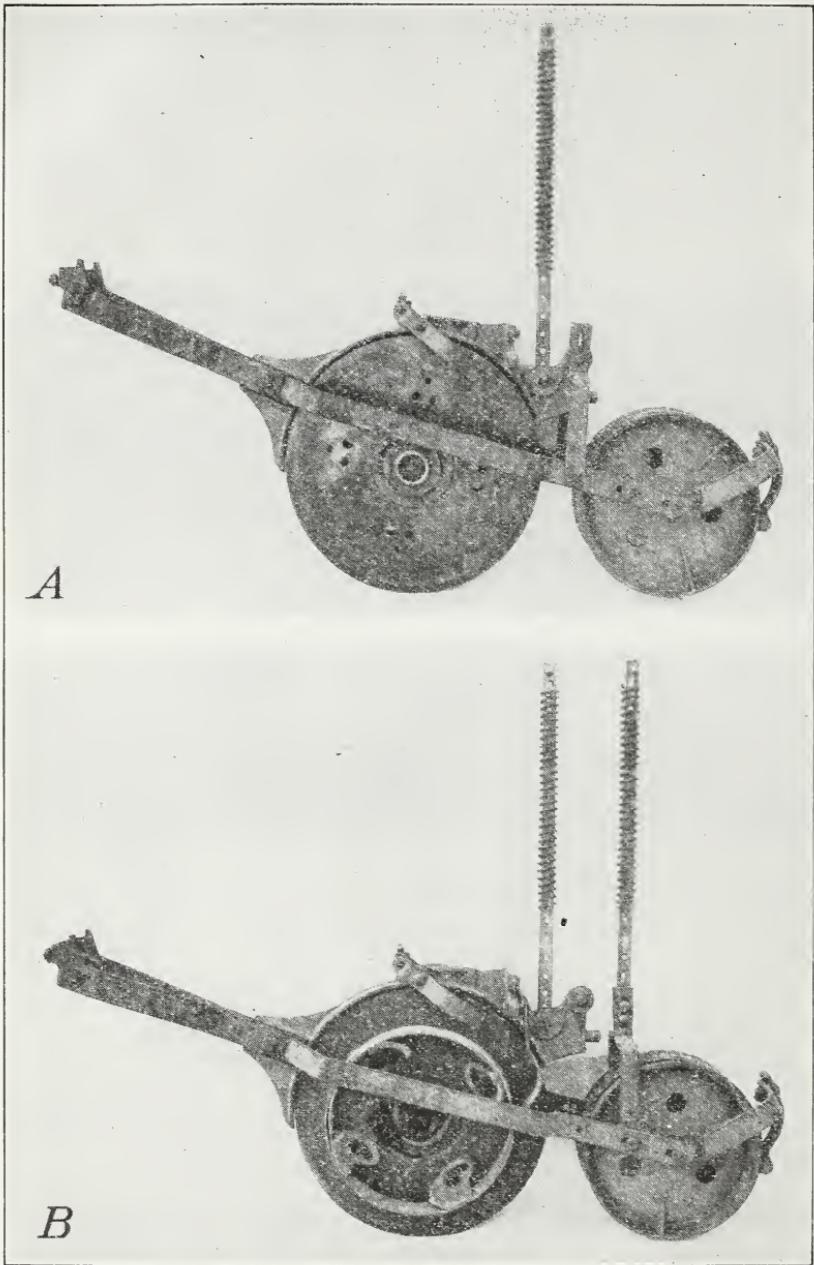


FIGURE 6.—The depth of planting with disk openers is usually controlled by depth bands on the disks: A, Planter with depth bands removed for deep planting; B, disk-opener set-up with depth bands and two pressure rods.

these bands can be changed to give the usual planting depths. Separate pressure rods are provided for the disk openers and the press wheels that are free to operate independently of each other. Occasionally the depth bands cannot be set small enough and in far enough on the disks to place the seed as deep as desired. In such cases operators commonly remove the depth bands altogether, but with no control the planting depth is liable to be uneven or too deep. This difficulty can be overcome on drills having provision for bolting the press-wheel drawbars (fig. 5) or pressure yoke to the disk-opener castings. The press wheels then control the depth of penetration of the disk openers thereby regulating the planting depth which can be set as described for runner openers. With such an arrangement independent pressure rods are not necessary on both wheels and disk openers as one set is sufficient if the tension on the pressure springs is increased. Figure 6 shows such an arrangement. It usually is not difficult to provide some simple device for similar depth regulation on drills that do not have this feature.

Depths of planting commonly range from $\frac{3}{4}$ to $1\frac{1}{2}$ inches depending upon moisture conditions and advancement of the season, late plantings usually being the deepest.

ROW SPACING

The width or spacing of sugar-beet rows varies from 18 to 22 inches, the most common distance being 20 inches; 18-inch rows are sometimes used in the nonirrigated districts where there are correspondingly wider spaces in the row. Spacings less than 20 inches are seldom used in irrigated sections, thus minimizing the covering of small beets when furrowing. Occasionally the rows are alternately spaced 18 and 22 inches, 16 and 24 inches, or 14 and 26 inches apart (12) and irrigation furrows used only in the wide spaces. This makes possible the use of larger furrows, particularly desirable where the ground surface is somewhat uneven and irrigation without flooding between the furrows is difficult. Where the rows are alternately spaced, it is desirable to use the narrow space for the "guess" row or space between adjacent planter strips. This spaces the irrigation furrows so that a standard doubletree and neckyoke can be used on the drills and cultivators and the horses can work at a normal distance apart. Row spacings are usually well established and uniform for any particular district.

Drills are provided with adjustment to space the openers at the usual row widths. Usually they can also be spaced to give the alternate narrow- and wide-row widths though it is sometimes necessary to use the wide space as the "guess" row because the openers cannot be set out far enough for the other arrangement. Where the wider row is used in the center of the drill and between successive drill strips, 80-inch doubletrees and neckyokes must be used on the cultivator as the same four rows which were planted at one time must be cultivated together. It is also desirable to use the long evener on the drill so that the planting is not done in the horses' tracks. Row markers should be set to make a mark at a distance out from the center of the drill equal to the width of planting; 80 inches, for example, for 20-inch or alternate 16- and 24-inch rows.

HILL PLANTING

Experimental development work by Bureau engineers with the hill planter has proved it is mechanically possible to place the seed in the soil at any desired distance between hills, to have any desired number of seed balls per hill, and to make the hills as compact as desired (fig. 7). At first it was thought the greatest difficulty in building such a planter would be in getting it to plant a sufficiently compact hill of seed. This proved not so difficult; in fact, it has been found desirable to modify the earlier planters to give more "scatter" in the hill to avoid too dense a growth of seedlings.

Commercially-built hill planters are now available and, with some adjustments, they can also be used for ordinary drill planting. They are equipped with different sizes of drive gears or sprockets so that



FIGURE 7.—A field of hill-planted beets.

the hills may be spaced as desired. The seed feed may be adjusted, and it has been found practical to use from one-half to one-fourth the amount of seed needed with an ordinary beet drill. The amount depends on the closeness of the hills and germinating conditions.

Bureau studies of the time required by field laborers in thinning beets have shown that under certain conditions there is a 20-percent saving in time by having the beets planted in hills rather than drilled. Other studies have shown that 20-percent more time is required where the beets are hill-planted. One factor in this variation is that some laborers do not readily become accustomed to the new conditions while others quickly make use of the advantage.

Soil conditions also affect the time required for thinning. In California on sedimentary soil the laborers were able to do the thinning of hill-planted beets in 20-percent less time than the drill-planted beets; on peat soil it took 20-percent longer to thin hill-planted than drilled beets, which contained more singles. Favorable

conditions produced more plants to the hill and heavier growth in the peat soil, and on it the laborers used neither hoe nor knife.

In thinning drilled beets, laborers, whenever possible, cut out the bunches with the hoe, leaving nearby single beets. Apparently hill-planted beets are so definitely bunched that laborers not used to them sometimes cut out the entire hill and fail to leave the desired single. This loss of hills in thinning ranged from 13.6 to 19.7 percent as compared to approximately 5 percent in cross-blocked, drilled beets. Such hill losses probably would not continue as laborers gained greater experience. A wider scatter of seed in the hill also would help reduce the number of beets accidentally cut out.

Commercial hill planters are now available which drop the hills with a check wire. If the planting is carefully done this permits two-way cultivation, and eliminates much of the hand hoeing. Checkrow planting may also speed up thinning as it is similar to hill planting.

Checkrow planters are built for 18-inch rows and drop the hills 18 inches apart in the row, which makes theoretically possible a stand of 19,360 hills of beets per acre. With the normal losses from thinning and other causes, this seems to be sufficient in the nonirrigated districts where moisture is likely to be the most important limiting factor of plant growth. The checkrow planter has therefore become popular in some of the nonirrigated areas.

In the irrigated sections theoretical stands of one beet every foot in 20-inch rows, or 26,136 per acre, and often more, are attempted. Final harvest stands, following normal losses during and after thinning, though somewhat less than the theoretical stand, are usually considerably higher than the theoretical stand with the checkrow planter. For this reason the checkrow planter has not been adopted in the irrigated districts.

BED PLANTING

Although planting of sugar beets on a flat seedbed is the common practice throughout most of the United States, a new planting method has come into use in the past few years in some sections, particularly in the Salinas Valley of California. It is known as bed or ridge planting because the beets are grown in beds formed from listed ridges. Head lettuce has been grown under irrigation in a similar way for years. In general, the equipment used for ridging, bed shaping, and planting is the same as that used for lettuce.

Two rows of beets, usually 14 inches apart, are planted on a flat-topped bed 22 to 24 inches wide on top and from 5 to 7 inches high. The beds are usually spaced 40 inches apart, center to center, and the furrows between them are 6 to 7 inches wide at the bottom. The spaces between rows are therefore alternately 14 and 26 inches, which results in the same number of rows in a field as when all rows are 20 inches apart. Figure 8 shows arrangement of typical bed-planted beets.

The advantages of bed planting as compared to flat planting are given by Robbins and Price (12, p. 14), as follows:

1. It is peculiarly adapted to an irrigated type of beet culture in that (a) it permits the irrigation which in cases may be necessary to cause seed germination, (b) it distributes water in deep furrows so

that none stands about the crowns of beets, and (*c*) it eliminates the danger of covering young beets in furrowing out.

2. It is especially adapted to beet culture where planting is done early and is followed by wet and cold weather, in that (*a*) seeds on ridges germinate earlier, which permits early thinning, cultivation, and irrigation, (*b*) the young plants receive good aeration and drainage, and (*c*) there is less tendency to crust formation.

3. In lifting two rows of beets 14 inches apart, there is efficient performance on the part of the lifting plow, on which shorter wings may be used, cutting down the draft necessary.

4. The cost of ridging is not high and according to experienced farmers is more than offset by the increased yields of beets on ridges as compared with those planted flat.

Bed planting also has certain disadvantages which must be weighed against the benefits:

1. Preparation is usually somewhat more expensive than for flat planting.

2. It requires specialized equipment quite different from that commonly used in districts where sugar beets are grown on flat seedbeds. Equipment designed for use on either flat or ridged seedbeds,

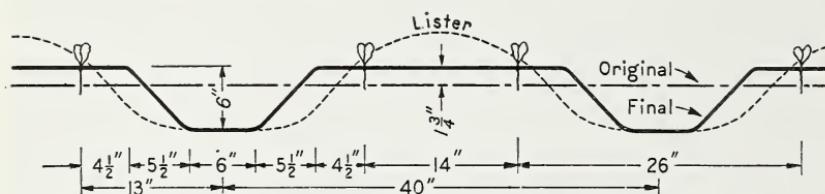


FIGURE 8.—Diagram showing shape of ground surface of bed-planted field.

such as planters, cultivators, lifters, and particularly harvesters, must have much more range of adjustment, a design which increases the cost. Power units must have approximately either 40- or 80-inch treads, thus eliminating many tractors now in common use.

3. It sometimes necessitates difficult and expensive methods for controlling weeds, particularly where ridges are constructed in the fall, winters are mild, and weed growth is excessive by planting time.

4. It is not adaptable to cross blocking or cross cultivation, practices which tend to reduce the spring labor peak where the flat seedbed is used.

5. It is not well adapted to large-scale production as planting units larger than six rows (three beds) have not proved practicable as yet.

6. It may not prove of any advantage in increasing production unless difficulty has been encountered with irrigation.

Bed-planting practice varies in different parts of the United States depending principally on the time and amount of precipitation. In California where the rains come largely during the winter, the first operation is fall listing. This is done with the ordinary lifter of one, two, or three bottoms equipped with markers to get uniform bed spacing. As most of the larger growers have track-layer tractors of around 30-drawbar horsepower for lifting beets, a common outfit for throwing up the ridges is a three-row lifter (fig. 9).

The ridges settle during the winter rains. The first early spring operation is harrowing with spike-tooth harrow, which levels the



FIGURE 9.—Listing up the ridges in preparation for bed planting.

ridge, corrects height, and kills weeds. Occasionally, when the winter is mild and rains delay planting, weeds get such a start that they are not killed by the usual harrowing or even by two harrowings. Additional harrowings flatten the beds too much and leave them loose. For such a condition long weeder knives, like those illustrated in figure 10, shaped from listed-corn cultivator blades or from plow steel, are satisfactory for destroying weeds along the sides of the

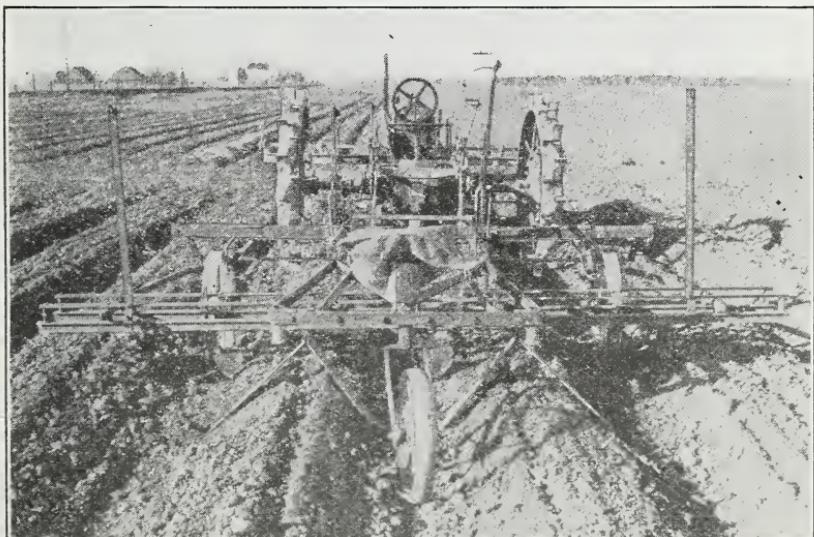


FIGURE 10.—An equipment set-up used for weed control on ridges preparatory to bed planting.

ridges. For the usual ridges formed with lister bottoms on 40-inch centers, satisfactory blades have a 29-inch cutting edge beveled on the under side and are set with the rear end 15 inches outside of and 8 inches below the front end. The blades are set so there is a small amount of clearance under the heel of the long bevel when cutting along the ridge, thereby giving some "suck." The forward ends are upturned so that they can be bolted against a vertical standard. Furrowing shovels will cut off the weeds in the furrows, and harrowing or the use of a large duckfoot behind the long weeder knives will clean up the tops of the ridges.

The bed is brought to correct shape with a sled former and is usually planted in the same operation. The sleds usually have special wings, shovels, or half shovels fastened to the front ends of the sled

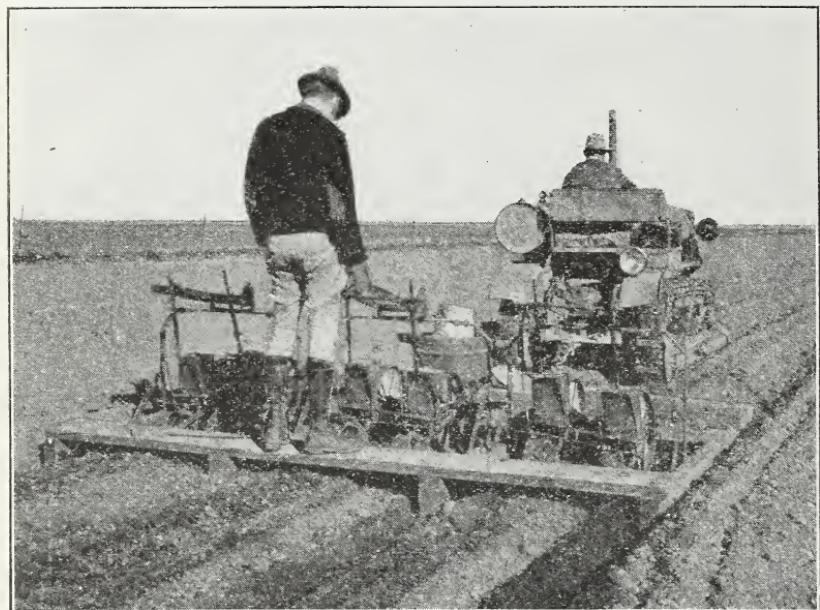


FIGURE 11.—A bed shaper and planter for three beds. Sled planters for two beds are also common.

runners to reopen the furrows. A crosspiece between the runners is used to strike off and level the bed to the right height. Small planters of the garden-seeder type are mounted on the sled frame so that each is held down by spring pressure and yet is free to follow any irregularities of the ground. The planter units and frames with lifting levers are bought ready made and the bed shapers are usually built locally in one-, two-, or three-bed units depending upon the acreage to be planted and the power available. A three-bed outfit is shown in figure 11.

Planting may be done in a separate operation. When the beds are comparatively low, an ordinary beet drill may be used without alteration except that the openers must be respaced to 14, 26, and 14 inches. A four-row drill so spaced is shown in figure 12. When, as is usual, the beds are 6 to 7 inches high or higher, it is necessary to increase the drill-wheel diameter or make changes in the frame

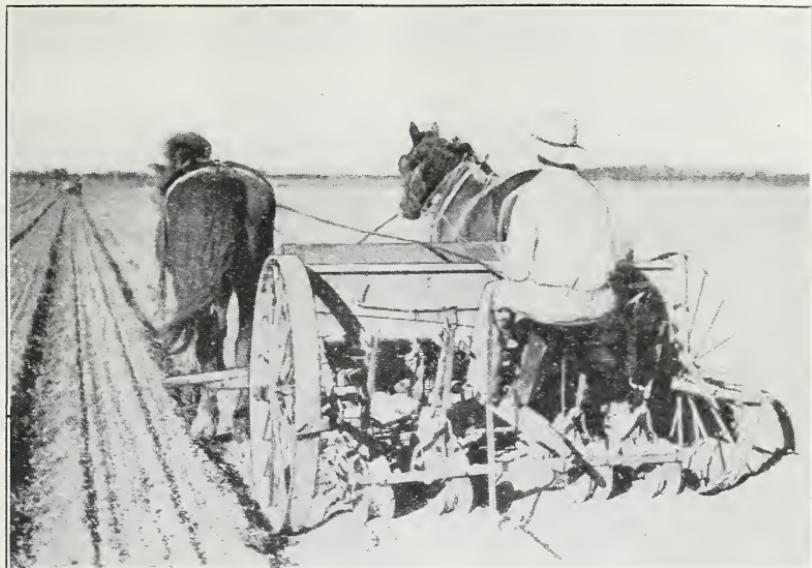


FIGURE 12.—An ordinary four-row sugar-beet drill with openers spaced on 14- and 26-inch centers, used for planting on low beds.

mounting to change the height of the openers. The openers must run at the right angle so that the seed will drop properly and be correctly covered and firmed by the press wheels. Figure 13 shows a



FIGURE 13.—Planting preshaped beds with an ordinary six-row drill equipped with special, large wheels.

six-row drill equipped with high wheels for bed planting and pulled by a small row-crop tractor.

In many of the irrigated beet-growing areas other than California, winter precipitation is comparatively light with consequent smaller advantage in making ridges in the fall. In fact, under some conditions, there is evaporation and loss of moisture during the winter, and in the spring the ridges are too dry for a satisfactory seedbed; hence, it is desirable to form the beds in the spring, and with as little disturbance of the soil as possible. Moreover, less power is necessary if beds are formed in spring from a fall-plowed field rather than in fall by using a lister and subsequently reforming into beds. Where it is desirable to form the beds in spring, it is possible to use a combination outfit which furrows, shapes the beds, and plants in one operation. Such equipment is now used to a limited extent.

The ridge and bed former illustrated in figure 14 was built for spring use. It is equipped with furrow-opening shovels much smaller than those on a lister. The small amount of soil lifted by these furrow openers is thrown on top of the undisturbed ground which is to

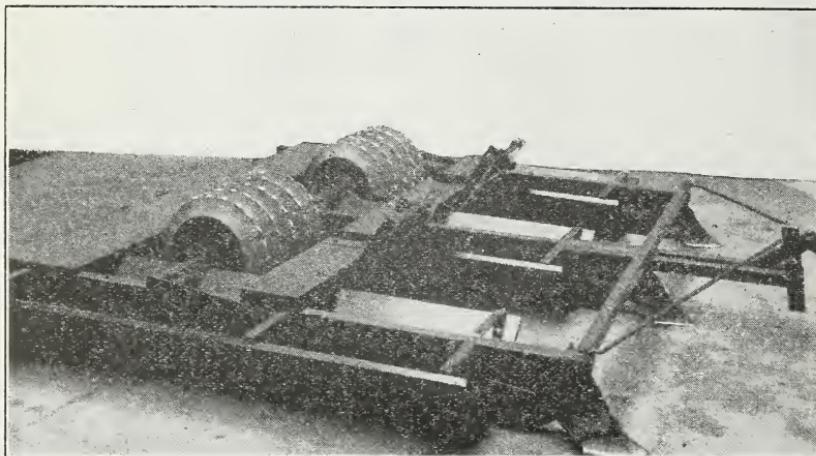


FIGURE 14.—Implement for furrowing and shaping beds in one operation in the spring.

be the base of the ridge. This loose soil is spread evenly and firmed with the roller sections. By thus forming the ridge, the seedbed is practically undisturbed. This is in contrast with a loose shoulder on the ridge directly where the seed is planted when the bed is formed from a too-dry, overwintered lister ridge.

CRUST-BREAKING EQUIPMENT

Crust formed by dashing rains or hail, or a very hot sun on moist soil, kills many beet seedlings. The tender sprouts unable to break through this crust curl over and die. Young seedlings already through the surface when the crust is formed are sometimes either sheared off by slight crust movement or pinched to death.

Many of the ordinary farm tools, such as the land roller and harrow, are used to break crust. Frequently the surface becomes hard while the soil immediately beneath is still moist, so that packing with the land roller is likely to do harm. Moreover, the roller is not so effective as it should be because it does not contact all of the area in

the beet row. The ordinary harrow is too abusive. It breaks most of the crust, but in doing this moves some of it laterally and shears off seedlings.

A Bureau test was made in Colorado of ordinary equipment to determine its abusiveness to beet seedlings that had started through the crust. The tools used ranked in the following order: Land roller, least abusive, then rotary hoe, blind cultivation, light spike-tooth harrow, and the ordinary spike-tooth harrow most abusive of all. The spike-tooth harrow destroyed approximately half the seedlings while the roller did practically no killing.

Special experimental equipment built for breaking soil crusts proved very effective without unduly damaging the seedlings. It consisted of units of spiked disks similar to small rotary hoe disks,



FIGURE 15.—Crust-breaker attachment to the beet cultivator.

separate units being used on each beet row. Of light construction and low first cost, it was used as an attachment to the ordinary beet cultivator as shown in figure 15. The spikes penetrate without causing side movement of the crust, and the units are self cleaning of surface trash or clods because alternate disks are of larger diameter, having large centers, which allows all disks to contact the ground in a line. Such units may be built by local blacksmiths or manufacturers and somewhat similar ones are now available from some implement manufacturers.

CULTIVATION

Beet cultivators, often used for beans and other crops, are available in two-, four-, or six-row widths to correspond to the size of planter used. It is necessary to use the cultivator on rows which

were planted together, that is, for example, a six-row cultivator cannot be used on beets planted with a four-row drill. Where fields are reasonably level and two planters are hinged or linked together side by side, two cultivators can be similarly attached and, with the steering mechanism controlling all wheels, one man can operate the double cultivator. The six-row cultivators have two caster wheels on the rear to straddle two rows. The others ordinarily have one caster wheel at the rear and the usual two front wheels.

Tractor-mounted cultivators are kept on the row by steering the tractor. Care must be exercised continually when using either a tractor-mounted or a pulled cultivator to keep from cutting out beets as the tools are usually set fairly close to the rows, but it is not difficult to keep on the rows when the planting has been reasonably well done.

Cultivator tools are available to meet practically any need or condition, and as nearly all cultivators have a double tool bar the tools can be set in practically any combination with plenty of clearance. Various types and widths of weeder knives and duckfeet are used for surface cultivation. Chisels, calf, deer, or bull tongues, diamond points, reversible shovels, and hoof shovels are available for deeper cultivation such as breaking up a hard subsurface condition, following tractor wheel or tracks, or opening up the soil ahead of an irrigation shovel. Disk weeders are available for early cultivation close to the beet rows and for very weedy or trashy conditions or for breaking a crust without tearing out seedlings. Shields can be used to prevent covering of small beets. Irrigation shovels are used for furrowing after cultivation or in combination with cultivation. Straight, rear, and side offset and pin-break standards are available for most cultivation tools.

There is a decreasing tendency to practice deep tillage, the cultivation being performed merely to control weeds except for special conditions of an impervious subsurface when chisels, diamond points, or similar narrow points are used for deeper penetration. The centers of the rows must, of course, be worked up deeply enough for irrigation furrows which are to be put in later in the season, and this loosening of the centers should not all be left to be done at the time of furrowing. A narrow calf tongue or chisel is usually used ahead of the irrigation shovel when furrowing.

Cultivation on bed planting is done with the regular beet cultivator, covering as many beds as were planted in one operation. When either one or three beds are planted together, the cultivator used on such plantings must have the double caster wheels at the rear spaced 40 inches apart as shown in figure 16, and for three beds a long toolbar is necessary.

The frames of most cultivators are not wide enough to permit extension of the main wheels to a 120-inch tread necessary to straddle three beds. However, the main wheels can be set with a 40-inch tread and depth-gage wheels can be used on the ends of the tool bar to hold the cultivator at an even cutting depth. Often the frame is extended to allow the main wheels to be set at the 120-inch tread, thereby making a steadier running outfit than with the wheels set 40 inches apart. Three-wheel cultivators can be used for three beds by running all three wheels on top of the beds in the 14-inch space between the beet

rows. However, this is less satisfactory than the 120-inch-tread cultivator, as more care must be used to keep the cultivator running steadily on the tops of the beds and, as the beets get larger, the wheels are liable to damage the leaves. In addition, when wheels are run on top, the shovels in the furrows need longer support standards.

Ordinary cultivation tools, such as sweeps or weeder knives are used on the tops of flat beds. Special curved knives, sometimes crescent shaped, are used on the sides of the beds. Furrowing shovels or duckfeet, sometimes following narrow chisels, are used in the furrows. Because of the danger of covering small beets, furrowing shovels are sometimes not used until after thinning.

The power used for the machine operations in growing bed-planted beets must be adapted to the practice. When horses are



FIGURE 16.—Two caster wheels must be used to straddle the bed when cultivating one or three beds.

used on ordinary four-row beet planters or cultivators for bed planting they must be used with 80-inch eveners and neckyokes as shown in figure 12. A one-bed sled planter is usually a sufficient load for two horses, and with such an outfit they would be used with a 40-inch evener. Three horses can be used on a two-bed planter if the sled is not too heavy or does not move too much soil.

The smaller track-layer tractors are usually of approximately 40-inch tread and are often used to pull a two-bed sled planter by offsetting the hitch and steering to overcome the side draft, which is not excessive. They are better adapted to use with three-bed planters as they ordinarily have sufficient power to pull the additional width and the draft is centered on the tractor. The same tractor then can be used on a three-bed cultivator more efficiently. Some of the small tractors can be obtained with approximately an 80-inch tread, and such a power unit can be used for a two-bed sled planter with

the draft centered on the tractor. For cultivation the same tractor can be used with the draft centered to pull one or two four-row or two-bed cultivators. It is not usually very satisfactory to cultivate four beds at once when only two were planted in one operation, even though each cultivator works the four rows planted together. To do it the beds must be very uniformly spaced, and the rows must be very straight.

Many ordinary four-wheel tractors are not adapted to use on bed planting as their treads will not fit either the 40- or the 80-inch rows. Wide-tread, four-wheel machines having approximately 80-inch treads can be used.

The row-crop type of tractor with a single front wheel or closely spaced double front wheels, and rear wheels adjustable to or spaced at approximately 80 inches, are well adapted to bed planting. They can be used for pulling two-bed sled planters and two-bed cultivators or are available with four-row, and, on the larger machines, eight-row tractor-mounted planters and cultivators. With some the beds can be formed with a shaper ahead of the rear wheels and planted with a unit built on the rear of the tractor. It is often desirable to shape the beds in a separate operation from planting, especially if the ground is moist, as sometimes the damp soil balls up on the planter openers and press wheels. If the beds are shaped ahead of planting, a six-row tractor-mounted planter can be used on the smaller row-crop tractors, which are not so satisfactory for eight-row equipment, planting two full and two half beds at each trip. This speeds up the planting and also the cultivation, as six rows can be cultivated at one time, thus utilizing the power of the tractor to better advantage.

The row-crop tractor with the wide front end on which both front and rear wheels can be set at approximately 40 inches (fig. 13) can be used for pulling six-row three-bed wheel planters where beds are shaped ahead of planting. This small tractor will not ordinarily pull a three-bed sled planter unless it is of very light construction and does very little bed shaping at the same time. The same tractor handles a three-bed cultivator nicely.

EQUIPMENT FOR LARGE-SCALE PRODUCTION

Four-row planters and cultivators are usually large enough to cover the sugar-beet acreage of most growers in ample time. However, there are some growers, particularly in California, who produce 500 to 700 acres or more and require larger planting and cultivation units. They commonly use track-layer tractors of approximately 30-drawbar horsepower with treads of from 40 to 44 inches and equipped with special narrow-track shoes usually 7 or 8 inches wide. With this tread and track equipment the tractor can be used with the usual 20-inch beet rows, straddling two rows, either for cultivation or harvesting. The equipment for planting, cultivating, and harvesting is adapted to such power units.

Planting on a flat seedbed is usually done with a combination of three and sometimes four regular four-row drills pulled as a unit. A usual hitch for three drills is to have the center drill hitched with a stub tongue to the tractor drawbar and to have a cross beam just ahead of the drill wheels and built into the drill hitch with its ends

diagonally braced ahead to the stub tongue. This crosspiece has clevises at its ends 80 inches out from the center of 20-inch beet rows, to which the tongues of the two trailing drills are attached. The tongues on the outside drills should be long enough so that there are approximately 4 feet or more between the wheel rims of the front and back drills. The longer these tongues, however, the greater the space required to turn and straighten out the drills. The three drills can be trailed when moving from place to place through lanes or gates or over bridges, and a clearance of 14 feet will let the cross beam pass while an 8-foot bridge floor will carry the drills.

A somewhat similar hitch, though less satisfactory for drills, is made by fastening a beam across the rear of the tractor to the hitch, bracing it with cables to the front of the tractor. The tongues of all three drills are hitched with clevises or otherwise to this cross draw-bar using as short a stub tongue as possible for the center drill,



FIGURE 17.—The usual three-cultivator hook-up uses a cross member attached to the tractor hitch to pull all three cultivators so that each may be controlled independently of the others.

usually about 4½ feet from clevis pin to axle. The tongues of the outer drills must be long enough to prevent interference on turns, usually about 12 feet, and even then short turns are not possible. This hitch, illustrated in figure 17, is satisfactory for cultivators and is the one generally used as one cultivator can be steered without interfering with the operation of the others and short turns are not necessary.

Another hook-up is made by building a stiff hitch between the stub tongues of the two outer drills. An extension back from the center of this hitch, braced diagonally and carried at the rear by a caster wheel, provides the hitch for the third drill. One satisfactory set-up uses a hitch point for the middle drill 3 feet behind the axles of the front drills and a 5-foot tongue, measured from the axle, in the third drill. With this hitch the outfit can be turned somewhat shorter and straightened up in a shorter distance than with the other hitches. However, it is a stiff hitch not well adapted to uneven

ground unless some special means is provided for flexibility. For moving from field to field the tongues of the two outer drills can be unbolted and the drills trailed. Otherwise a clearance of approximately 21 feet is required.



FIGURE 18.—A three-drill hook-up which can be turned and straightened up in a narrow headland.

One man can more easily tend the three drills when hitched as just described as he can walk back and forth on the hitch as shown in figure 18. More than one drill operator is usually used with the multiple-drill combinations, however, sometimes one on each drill, particularly if there is difficulty with clods or trash or if fertilizer is used.

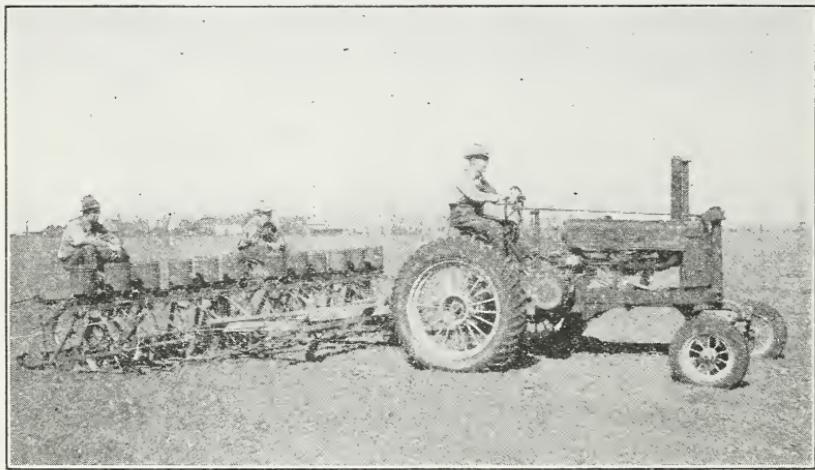


FIGURE 19.—Two six-row planters pulled side by side with a stiff hitch between which requires a headland of minimum width.

Some of the newer drill combinations consist of two six-row drills. The six-row drills allow the use of six-row cultivators with a saving of man labor as one less man is required on a 12-row cultivator hook-up and permits 6-row cultivation with the smaller row-crop tractors,

thereby utilizing their power more adequately. Some drills with one opener outside the main wheels can be used side by side without any rebuilding by using a stiff hitch and a connection between the

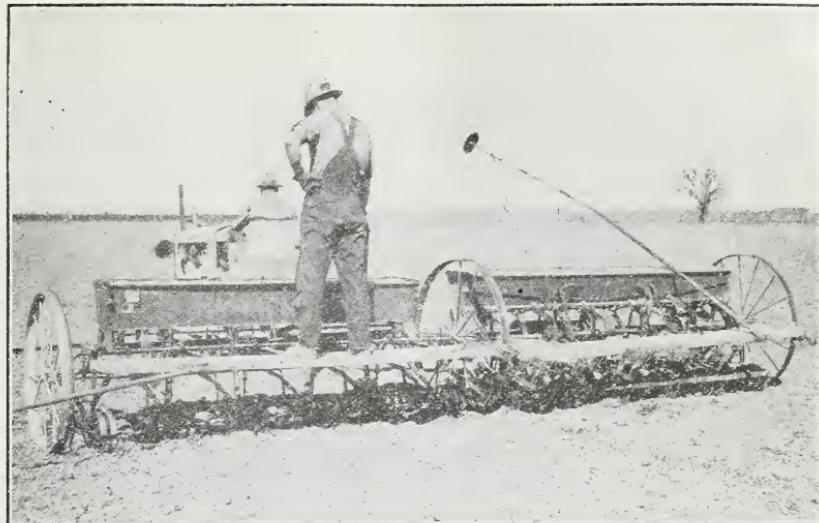


FIGURE 20.—On drills with the main wheels outside of all the openers it is necessary to remove one wheel and stub axle in the center to connect two drills abreast.

two drills as shown in figure 19. Some drills with the main wheels outside of all the openers are so made that one wheel and the stub axle can be removed and the open end of the drill hinged to the end of another drill as shown in figure 20. Drills with solid axles clear



FIGURE 21.—The usual three-drill hook-up uses a cross member built into the hitch of the center drill to pull the two outer drills.

through cannot be used side by side unless the openers can be set in toward the center far enough to provide the desired spacing of rows.

When two drills cannot be used side by side they may be staggered one behind the other. Tongues pinned to a beam across the tractor hitch can be used but they are not so very satisfactory as short turns

are possible only one way and a figure-8 turn must be made at the other end of the field. Such a hitch is used for cultivators, however, as all turns can be made one way by skipping a cultivator width each new trip through the field. A more convenient two-drill hitch can be made using a modified A-frame. Such a hitch is somewhat like the three-drill hitch shown in figure 18 with one of the outside drills taken off and the end of the stiff hitch in front entirely supported by a caster wheel ahead of the trailing drill. Other hitches for two and three implements are shown and described in a South Dakota bulletin (16).

Four-drill hook-ups, though uncommon, may be made by using two drills in the center side by side with the openers set in for proper row spacings. A beam across the hitch of the two drills is used to carry the tongues of the two trailing drills similar to the three-drill hook-up shown in figure 21. Four cultivators are pulled with the beam across the tractor drawbar as shown in figure 22.

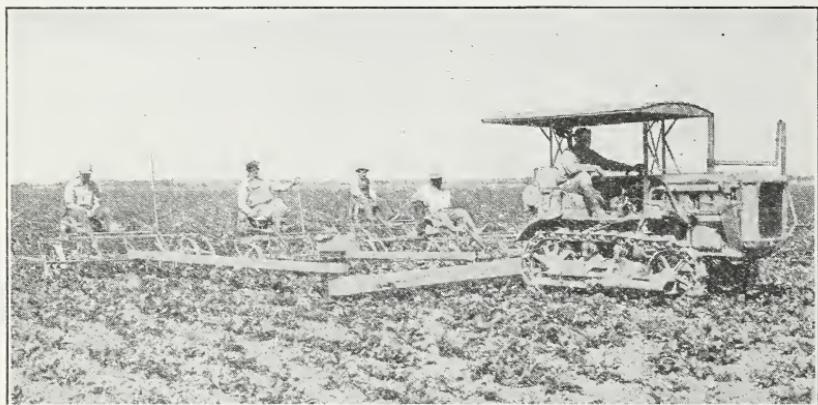


FIGURE 22.—Four cultivators are pulled with a hitch consisting of a beam across the rear of the tractor.

On large fields where the drill combinations are used, headlands of 24 to 32 rows are planted across the ends to finish the field. All irrigation ditches within the field are plowed in each year before harvest and the whole field is worked as a unit for planting, cultivating, and furrowing. The beets are usually harvested with a 2-row lifter pulled with a tractor of around 30-drawbar horsepower though some digging is done with 3- and 4-row lifters pulled by larger tractors.

CROSS BLOCKING

Cross blocking of sugar beets by machine is described in another publication of the Department of Agriculture (7). Briefly it consists in using an ordinary beet cultivator working across the rows to cut out short lengths of row, leaving uniformly spaced blocks of beets for hand thinning. It has the advantages of removing competing plants at the proper time (fig. 23), especially on larger acreages; it aids in the control of weeds and saves labor; hence the practice has been quite generally adopted. Figure 24 shows the use of adjustable weeder knives in cross blocking.

The developments in cross blocking in the last few years have been (1) the shortening of the distance between beet blocks (2) the form-



FIGURE 23.—A field of cross-blocked beets.

ing of smaller sized blocks, and (3) the general use of simplified cultivator tools.

The shortening of the distance between blocks results in better stands as measured by the number of thinned beets per 100 feet. A

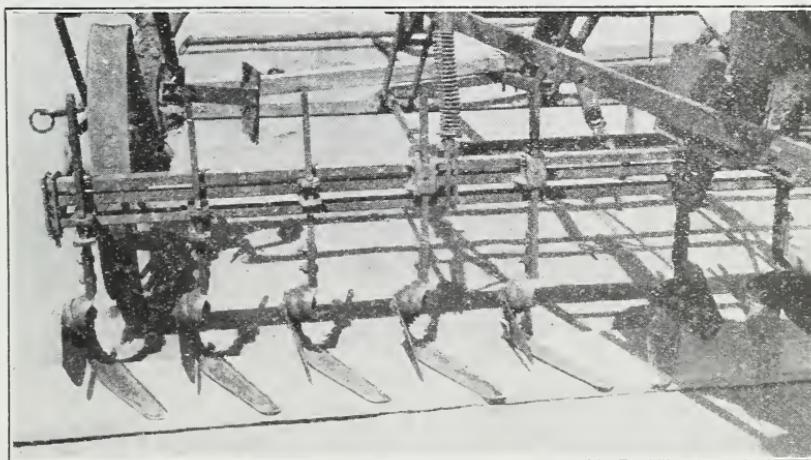


FIGURE 24.—Adjustable weeder knives are particularly adapted to use in cross blocking as they can be set to give the desired width of cut and to throw a minimum of soil.

commonly used spacing is 10.5 inches from center to center of beet blocks. With the practice of leaving smaller beet blocks, commonly 3 to 3½ inches, the number of remaining "singles" is increased over

the number left in earlier trials, thus making hand thinning still easier.

Practically all cross blocking may be done with either the knife weeder or the duckfoot shovel, the requirement being that the blade be nearly horizontal so that there will be a minimum of soil movement. For this reason an adjustable weeder knife is good. It is also desirable to use the kind of duckfoot shovel illustrated in figure 25, because of the flat blade and because the rear gooseneck shank reduces trash gathering to a minimum. In soils which will not scour when the blades are set horizontal, the blades must be given slight inclination or "suck."



FIGURE 25.—The duckfoot blade for cross blocking should be nearly flat, and the gooseneck aids in keeping implement clear of weeds.

this treatment is difficult to measure, but plants remain wilted for hours and may die.

To lessen damage to beets and possibly lighten the difficult task of thinning, several substitutes for the hoe have been made. The hand thinning knife (fig. 26) strapped to the fingers in a manner similar to the corn-husking peg, permits the laborer to use the fingers of both hands, to use the open hand for support, to use either a forward or backward stroke, and above all, to reduce damage to the remaining beets. Lightweight hoes and blades somewhat similar to the regular hoe in shape, but requiring a pull through the soil, instead of the customary chopping action, have their advantages.

On some very productive soils growers prefer spaces of 8 or 9 inches between beets. It has been observed that where the closer spacings are practiced, the average spacing is seldom less than about

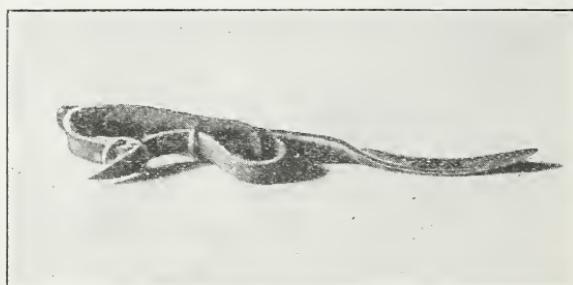


FIGURE 26.—Hand thinning knife—a substitute for the hoe.

3 or $3\frac{1}{2}$ inches more than the width of the hoe used. That is, when using a hoe with a 5-inch blade, the closest spacing usually obtained is around 8 to $8\frac{1}{2}$ inches. The use of 7-inch hoes automatically increases the beet spacings to at least 10 inches.

Considerable agronomic experimental work has been done on spacing and space requirements of sugar beets as correlated with yield (3, 6, 14, 17). However, the spacing is usually fairly well established for a district, or recommendations are made by the sugar company fieldmen.

BEET LIFTERS

The beet lifters most generally used are of the two-row tractor-drawn type used in California, and the single-row horse-drawn type used in other areas. These vary in the amount of power required, in their ability to loosen the beets, and especially in their adaptability to the mechanical harvester.

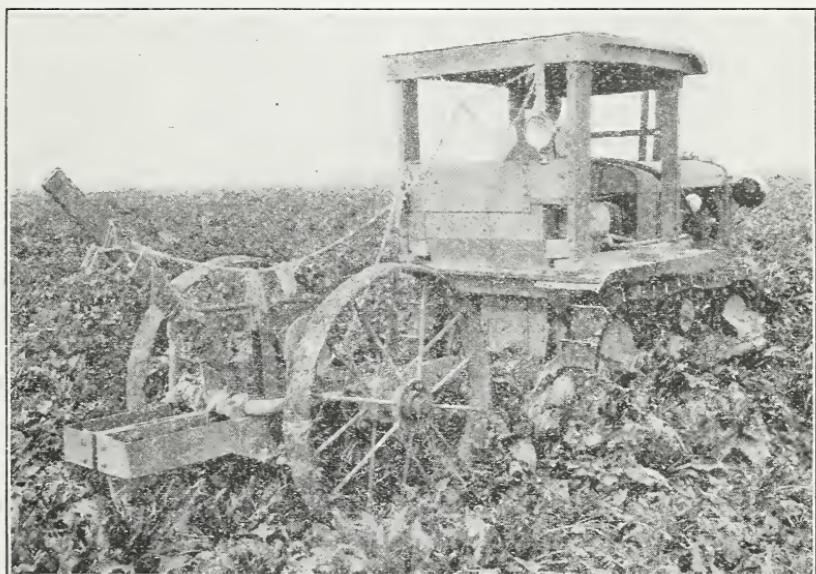


FIGURE 27.—The usual beet-lifting outfit in California loosens two rows at once.

The usual outfit for lifting beets in California consists of a single standard subsoiling chisel to the bottom of which is bolted a pair of wings or shares which run under the beets. This loosens two rows at a time and usually is pulled by a track-layer type tractor of from 25- to 30-drawbar horsepower as illustrated in figure 27.

The lifter commonly used in other areas works one row at a time, is usually pulled by two to four horses, and does the lifting by having two "points" or blades straddle the row. Because the lifter blades scoop the beets loose, they may be run shallower than the subsoiler type, thus moving less soil and requiring less power.

Modifications of these two types of lifters have been made principally for use in lifting ridge-planted beets where the alternate rows are close together, usually only 14 inches apart, and for use with the mechanical harvester.

The plow or lifting point of one harvester being developed consists of a comparatively narrow blade which runs directly under the beet row. This blade is supported by a single arm from one side. The blade is given a slight inclination upward toward its rear edge so that, as it goes through the ground, it gives the beet a lift as well as loosening the soil around it. The chief objections to this type of lifter are that it, like the subsoiler type, has to go deep enough to get entirely under the row of beets and it is more difficult to keep on the row properly to loosen the beets.

Experimental tests were made by Bureau engineers near Davis, Calif., on several types of beet lifters. Three principal observations were made on each type. The first was on the effectiveness of loosening the beet from the soil, the second on draft of the lifter, the third on the adaptability of the lifting device for use on a mechanical harvester. Of the three, only the draft could be determined with accuracy. The other two were matters of observation, though the effectiveness of loosening was more or less definite. To give results as nearly comparable as possible each type of equipment tested was mounted on the same carrier frame. This carrier frame was a new subsoiler chassis, such as is used commonly with a single subsoiler standard and beet wings for lifting two rows of beets.

Provision was made to quickly determine in the field the depth of penetration of the lifter so that comparable draft tests might be made. The drafts were taken by using a recording and integrating traction dynamometer. All tests were run at practically the same speed. The results are shown in table 2.

TABLE 2.—*Results of beet-lifter tests*

Type of lifter	Tests	Average pull per row lifted	Type of lifter	Tests	Average pull per row lifted
	Number	Pounds		Number	Pounds
Double shoe, single-row type	{ 4 3 7	{ 746 803 843	Single-arm, single-shoe running-under-beets type used on mechanical harvester	4	812
Subsoil—chisel with wings, 2-row type ¹	{ 11 4 4	{ 1,109 932 1,079			

¹ Draft for 2-row machine is twice the recorded amount.

Of the beet-lifting equipment tested or observed in use, that which is apparently best adapted for use on a mechanical beet harvester is the type using two puller shoes or blades per row. This type elevates the beets appreciably more than the others and keeps them nearly vertical while being lifted. It raises them so that if a pair of elevator chains were placed above it, the tops would be pushed into the chains and only a few would be missed. Even when the lifter is pulled slightly off the row, it still lifts satisfactorily. It leaves the beets looser than the regular standard-with-wings type of lifter, all beets being loose enough to be pulled readily by the tops.

When set to run comparatively shallow or at a comparatively steep angle, this lifter raises the beets so high they roll out between the rows behind the lifter. On a mechanical harvester with elevating

chains, the high lift is desirable. When lifting for hand topping, the high lifting rolls beets into the furrow so that the machine on its next round runs over and crushes some of them.

Draft tests conducted in 1932, the object of which was to find the draft of the two-row type of lifter at different depths and a comparison of this type with the single-arm, single-row machine used on the harvester, gave the following results:

Depth of point below center of row:	Draft pounds
15½ inches ¹	4, 000
16½ inches ¹	4, 220
18 inches ¹	4, 440
12¾ inches ²	2, 872
12¼ inches ²	2, 938
Draft test on the single-arm lifter point in the same field	840

¹ Deeper than normal.

² Normal.

In California, bed-planted beets are harvested by using the subsoiler-with-wings beet plow which lifts two rows at once. Such a lifter is shown in figure 27. Under usual conditions a 25- to 30-horsepower tractor is used to pull it. The subsoiler standard goes between the two close rows, the wings extending under them. Modifications of this type of lifter have been used successfully. One of them has the subsoiler frame carrying two standards which straddle the two close rows and have inward offset points that pass almost under the beets. With two standards, which make a more stable machine, there is no need for the wings used on the single-standard plow which cause heavy draft and sometimes cut off long beets. The horse-drawn lifter common in most beet districts can also be adapted to the bed rows by making a few changes.

MECHANICAL HARVESTERS

Mechanical harvesting of sugar beets presents many difficulties, some of which are not readily apparent. The lack of uniformity of the crop as it stands in the soil ready for harvest is probably the greatest difficulty to overcome. The beets vary in size and the lower leaf scars, at which point the roots should be topped, are much farther below the top of the crown on the larger beets than on the smaller ones. The spacing in the row is irregular and the beets often occur as doubles. Some grow with their crowns several inches above the ground while the crowns of others are at or slightly below the surface.

The leaves of some beets are large and upright while on others they may be short and more or less horizontal. There may be a large clump of vigorous leaves early in the season and only a few left at the end of the season in districts where the crop ripens well. Some beets when small may have been injured by disease, such as downy mildew, and instead of the usual large, strong leaves coming from the center of the crown, there may be many small, short leaves all over the crown or around the edge. The leaves may be partially frozen and slippery late in the season.

The soil may be fairly loose, moist, and mellow and break away from the roots easily. It may be nearly muddy at times and stick to the roots. Or it may be very dry and hard at harvest time, and

break up into large hard clods from which it is very difficult to separate the beets. Weeds such as morning-glory or bindweed may sometimes be very bad. These are the more common natural difficulties and to them man has added variable row spacings of from 18 to 24 or 26 inches or alternate spacings of 14 and 26 or 16 and 24 inches.

Experimental work on machines for harvesting sugar beets started years ago and a great deal of time and money have been spent on it both in this country and in Europe. Many patents have been granted on sugar-beet harvesters, and predictions were made nearly 20 years ago that in a few years much of the acreage would be harvested by machine. Yet today practically all of our sugar beets are still harvested by tedious, bended-back, hand labor. However, progress has been made, particularly in the last few years, and harvesters have been developed to the point where they can successfully do the arduous job of harvesting where field conditions are favorable.

Practically all attempts to build sugar-beet harvesters have been made on one of two basic types: (1) The one that tops the beet while still in the ground, subsequently lifting it from the soil and separating it from the dirt, clods, and leaves; (2) the one that lifts the beet and conveys it to a gage and knife where it is topped in the machine. Contrary to the prevalent belief, it is not at all impractical to top satisfactorily by machine. Other problems have been found more difficult.

Most builders have worked on the development of the type that tops the beets while still in the ground where their firm position facilitates topping. There are two difficulties. Beets are not of uniform height and require a topping-height gage which moves up and down very rapidly and is liable to overturn high beets, especially in loose soil, or break them off.

It is also difficult, especially in hard soil, to get a sufficiently low cut on beets with subsurface crowns.

Gages for this kind of harvester have been of three types: (1) Sliding fingers or shoe, (2) wheel, and (3) endless track. The gage or finder rides down the beet row, its height determining the height of cut made by the knife immediately behind. The knife may be either a stationary blade or a revolving disk. When the beets are fairly uniform and the soil sufficiently firm to hold them, satisfactory machine topping may be done.

With this method of harvesting the greatest difficulty (considered insurmountable by some) has been to lift the beets and separate them from the clods. No satisfactory clod crusher has been devised that will not also bruise the beets. Attempts to separate the beets mechanically from the clods have failed. It has also been found impractical to hand-pick either clods or beets from the conveyor.

The most recent developments in beet harvesters have been in the type that lifts the entire beet by its leaves, conveys it to a gage and topping knives, and disposes of the beet in one direction and the tops in another.

The elements of this type of harvester are:

1. A modification of the commonly used beet lifter, for loosening the beet.
2. A conveyor to grasp the beet top and elevate it.

3. A gaging device to hold the beet in position while a knife tops off the desired amount of crown or leaf scar.
4. A conveyor or hopper to carry the beets.
5. A conveyor or hopper to carry the beet tops and leaves.

The type of lifter adaptable to the harvester has been discussed under the subject of lifters.

The conveyor for elevating beets by their tops has a more difficult task than the similar elevator on a corn harvester. Beet tops, sometimes by the nature of the plant and sometimes because they are frozen, are liable to lie flat on the ground. Some of them are very short and others are well over knee high. The conveyor chain with a side bend may run almost parallel with the ground at its front end and be able to grasp the beet top 2 inches from the ground.



FIGURE 28.—Mechanical sugar-beet harvester leaving the topped beets and beet tops in windrows.

Rubber facing seems necessary on the conveyor chain so it will hold the tops in a firm grip and yet not break the more brittle ones.

It is important that the gathering points which guide the beet tops into the conveyor be smooth and so shaped as not to collect dead leaves or break off high beets.

The heart of the machine is in the topping device and the gage for determining the proper height of topping. The harvester illustrated in figures 28 and 29 uses a pair of roller bars which take the beet from the elevating conveyor and with considerable force carry it up against the gage to be placed for proper height of cut and then carry it into the power-driven knives for topping.

When beets are topped within the machine it is possible to salvage the tops more satisfactorily for cattle feed. In trips back and forth the clean tops may be placed in close piles (fig. 28) that make a windrow.

While the topped beets are being conveyed loose leaves and adhering soil are shaken out. In some sections, where it is necessary,



FIGURE 29.—This type of harvester lifts the beets and tops them in the machine.

the hand laborer bumps the beets to loosen the soil. The mechanical harvester, however, does this work better, and mechanically harvested beets carry much less dirt tare.



FIGURE 30.—The beets are dumped in piles; a conveyor might be used to elevate them directly into the truck.

A series of tests on the quality of topping with the mechanical harvester in Colorado in 1936 yielded the results shown in table 3

TABLE 3.—*Effects of mechanical harvester on topping sugar beets*

Average weight of beet in sample (pounds)	Loss due to low topping Percent	Top tare Percent	Average weight of beet in sample (pounds)	Loss due to low topping Percent	Top tare Percent
0.935	2.2	1.5	1.7	0.65	3.5
1.6	.9	2.5	1.28	.75	3.25
0.65	3.9	2.2			
0.56	3.1	2.7	Weighted average 1.1	1.6	2.6

The beets harvested by the harvester, as well as hand-harvested beets, were sampled at the dump and the dirt and top tare of the entire field averaged as follows:

	Percent
Machine-harvested beets	5.44
Hand-harvested beets, same farm	4.94
Hand-harvested beets, entire dump, for same period	5.34

When these comparative tests were run, the product of the machine was measured as it came from the machine without any hand trimming.

The tare of the hand-harvested and machine-harvested beets is practically the same. The machine is likely to leave more good beet on the tops than hand laborers, especially on small beets. The harvester may be adjusted to cut lower or higher; and when the beets are fairly uniform, the amount of good beet left on the tops can be reduced to considerably less than 1 percent.

Studies of harvesting with hand labor in California in 1935 by the Bureau showed the surprisingly high average loss in missed beets of 2.4 percent with a standard error of ± 0.29 . In some cases the loss was considerably greater and in others, where supervision of labor was more strict, the loss was somewhat less. Under favorable conditions in California the mechanical harvester missed no more beets than hand laborers and during the Colorado tests just mentioned, the loss was less. As the missed beets can be easily seen, they may be economically gathered following the harvester. In some of the studies there were many days of operations when practically no beets were missed by the machine.

A single-row harvester averages from one-third to one-half acre per hour, depending on the speed of the tractor and the length of the rows. At $2\frac{1}{2}$ miles per hour it would take $1\frac{1}{4}$ miles of travel and 30 minutes of time to cover a quarter of an acre which would make a good-sized truckload of good beets.

The operating costs are for the tractor and operator and for the harvester operator. These items alone amount to considerably less than labor costs of hand topping. The real cost of mechanical harvesting must include depreciation, interest, and repairs on the harvester which, when conservatively estimated and added to operating costs, when harvesters are commercially built, probably will still be less than present hand-labor costs. In addition, the peak demand for hand labor for harvesting will be greatly reduced.

DUMP BODY

In most of the beet areas the beets are dumped from the side of the truck or wagon. Some dumps necessitate dumping from one side and some from the other. A box that may be dumped from either

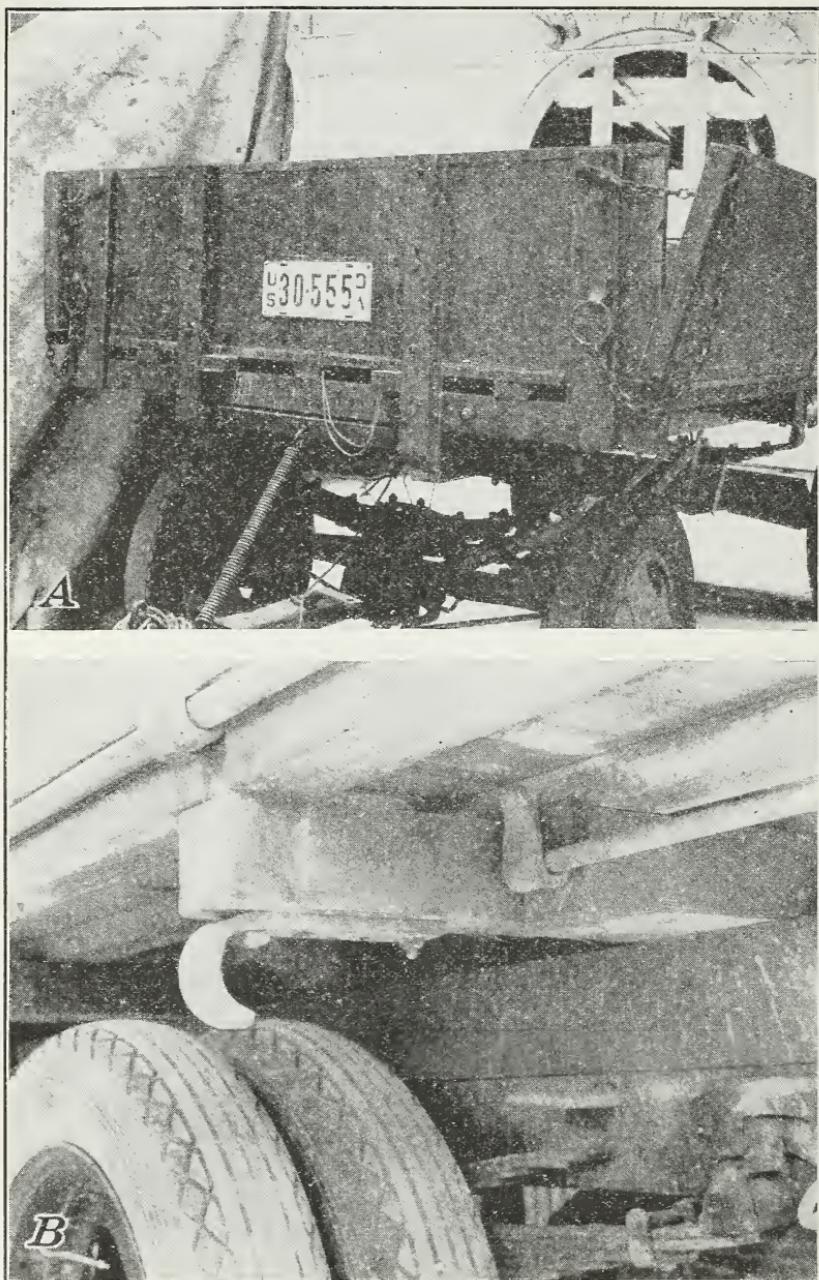


FIGURE 31.—Dump body which may be dumped from either side: A, The beet box; B, details of dumping mechanism.

side is shown in figure 31. When not being used for hauling beets, it may be locked to prevent bouncing when being hauled at higher speeds over rough roads.

The plans may be modified to suit different chassis sizes and may have more or less floor supports, depending upon the use to which it is to be put. The pipe hinge for the side doors makes the box practically grain-tight. The endgate may be built in sections so that the center section would be removable as a grain gate. The side-board chains permit the sides to be held tight shut, in a horizontal position, or to hang vertically down.

HAULING

Originally horses were used to haul all beets. Under some circumstances this is still desirable, especially when the haul from the field to the dump is short. There is a definite advantage in using horses in the field since the hauling and loading is an intermittent operation, and frequently the field is soft, causing difficult truck starting. The disadvantage, aside from slow speed, of the horse-drawn beet wagon has been the heavy draft caused by the wheels cutting into the soft field.

In an attempt to gain the advantages and eliminate the disadvantages of horses for hauling beets, the combination trailer and farm wagon is used. It is equipped with truck-sized pneumatic tires which have much less rolling resistance in the field and permit high-speed highway travel. The tongue is telescoping (13); when pulled out it is the proper length to use with horses. The team is able to make frequent starts and stops with little loss of time on the part of the man doing the loading. Heavy loads may be hauled, even though they may be too heavy for continuous hauling, since the frequent stops give the horses ample rest.

The horses pull the comparatively large load of beets from the field to the highway. The truck driver, who may have a smaller load of beets, is able to back his truck to approximately the correct place to couple onto the horse-drawn wagon which has now become a trailer. Since the tongue is telescoping, he is able to make the connection readily alone. By backing the truck, the tongue telescopes and locks into its short position. The truck driver with his two loads goes to the dump. A second trailer wagon being loaded in the field is ready by the time he returns. The two men may put a small load on the truck and by changing drivers each trip make the loading job less arduous.

The advantages of this system are: Greater ease in getting the loads from the field; less truck driver's time per ton of beets hauled; less driver's time lost per ton of beets when delayed at the dump; more efficient use of loader's time; and more efficient use of the truck.

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